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FLUID HANDLING 2: SURGICAL APPLICATIONS

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PURPOSE:

To investigate and demonstrate the methods proposed for managing fluids and particulate debris during minor surgery on Space Station Freedom (SSF.)

OBJECTIVES:

Using simulated capillary, venous and arterial bleeding in a minor surgical setting,

- Evaluate and test methods of local barrier and fluid absorption.
- Evaluate and test local mechanical suction.
- Evaluate and test laminar flow with suction.
- Evaluate and test use of an absorbant barrier curtain.
- Evaluate and test laminar flow/suction containment of cautery fumes.

OVERVIEW:

A KC-135 parabolic flight test was performed on May 1, 1990 with the goal of investigating proposed techniques for fluid management during minor surgical procedures aboard SSF. The flight followed the standard 40 parabola profile with 20-25 seconds of near-zero gravity in each parabola. Four experimenters were involved in the study. The equipment being

evaluated (suction and laminar flow device) had flown previously in evaluation of a dental procedure scenario. Two of the investigators were participants of that earlier flight. While the equipment performed satisfactorily in the dental simulation, the purpose of the current flight was to reconfigure the equipment in support of a minor surgical situation in order to evaluate its efficacy and establish clear requirements for the actual flight hardware.

To accomplish the study the Health Maintenance Facility (HMF) medical restraint system (MRS) was deployed as for surgical use and a mannequin suture arm was restrained to its surface. The surgical area was established as for performing minor surgery with standard tray and suture instruments employed. (See photo 1.) No prepping or draping of the arm was done.

In order to simulate the various types of bleeding, two long intracath catheters were placed into the suture arm at different angles with the tips positioned at the laceration opening. One catheter was angled as if running parallel to the surface and the second catheter was angled as if coming from deep within the tissue. Colored water was placed into 60cc syringes which when attached to the intracath catheters could be used to simulate different types of bleeding depending on the degree of force applied. (See photo 2.) In this manner the investigators were able to reproduce small to large amounts of fluid at different pressures originating from different aspects of a laceration. This technique was practiced in the lab prior to flight and proved to be an effective although simplistic simulation.

The laminar flow/suction particle containment device used was the prototype developed for KRUG Life Sciences by Dr John Young. (For specific description and specifications see the earlier flight report submitted by Dr Young "Dental Simulation using Laminar Flow" January 1990.) The device consisted of a hand-held suction device with on/off control similar to most surgical suction (see photo 2) and a laminar flow device. The laminar flow device directed a current of horizontal air flow above and across the surgical site. Directly opposite to the air originator was a suction funnel trap that collected fluid and particulates from above the site. These devices were adjustable in height and were bracketed around the surgical site while leaving enough room for the surgeons to maneuver without compromising the sterile field.

The sequence for the study was as follows:

Parabolas

- 1 - 5 Demonstrate use of local absorbant barrier
- 6 - 10 Demonstrate use of local suction
- 11 - 15 Demonstrate use of laminar flow /suction
- 16 - 20 Demonstrate use of barrier sheet
- 21 - 25 Evaluate integrated system for capillary flow
- 26 - 30 Evaluate integrated system for venous flow
- 31 - 35 Evaluate integrated system for arterial flow
- 36 - 40 Evaluate integrated system with cautery fumes

BACKGROUND:

In performing surgical procedures, whether major or minor, there are several basic principles that should be adhered to in order to meet today's standards of medical practice. Included among these are the principles of sterile technique, proper exposure and visibility, and hemostasis and fluid management. In previous zero-gravity experience it has been found that actual surgical technique is not difficult to perform once the surgeon has acclimated his or her fine motor skills to the absence of gravity. Other challenges that have had to be met are those of operator and equipment deployment and restraint, and these have been done using the medical restraint system with various attachments.

Some KC-135 flight experience has been accumulated in the handling of fluids in medical scenarios and with the use of suction. (See KC-135 reports for Fluid Handling and Transport Suction.) It has been found that medical fluid management is not a simple matter due to the unusual behavior of fluids in zero-gravity. Consequently there has been concern over the ability to maintain a clear and sterile field during surgical procedures. The capability to provide proper hemostasis must be developed to keep the operating field clear, to limit the need for blood and fluid replacement, and to minimize the chances for wound infection. It is hoped that with simple surgical procedures (with limited bleeding, fluid loss or contamination) very basic methods of barrier and suction will suffice to provide proper control. However, it is realized that preparation must be made for more complicated or contaminated situations in which greater flexibility for hemostasis and containment is required.

This flight experiment was designed to study some basic methods of surgical fluid management both independently and in an integrated fashion. Based on the dental scenario experience in zero-G using the laminar flow device, it was felt worthwhile to adapt that equipment for use in a minor surgical simulation and test its effectiveness with varying degrees of bleeding. Separate flight studies are being performed looking at an inclusive operating canopy or enclosed bubble concept.

MATERIALS:

- Prototype MRS with restraints
- Mini-racks with stowage drawers
- Instrument tray with minor surgical instruments, suture
- Laminar flow/particle containment device with power sources
- Suction tubing with various tips
- Mannikin suture arm with pre-placed catheters
- Syringes and pre-made simulated blood
- Various towels, drapes, gauze
- Cautery device and orange
- Waste containers
- Misc. support materials (tape, straps, etc.)
- Video

PERSONNEL AND SUPPORT:

- 4 investigators (one physician, one dental surgeon, one biomedical engineer and one video-technician)
- Videorecording performed by technician; still photography performed by non-dedicated NASA photographer. Post-flight worksheets completed by all.

TEST PROTOCOL: (*See attached "Fluid Handling 2: Worksheet"*)

RESULTS AND DISCUSSION:

Local Absorbant Barrier (*See photo 3.*)

Two types of absorbant gauze were used - sterile 4X4's and loosely wadded Kerlix wrap. Both worked fairly well although the rapid wicking action of the Kerlix made it perform in a superior manner. As with previous fluid handling flights, the wicking action was the main determinant of utility since rapid blotting caused the fluid bolus to fragment and escape. For simple capillary and venous bleeding the local barrier functioned similarly to terrestrial practice and could be used for a majority of the fluid management needs.

Local Suction (*See photo 2.*)

The use of local suction was simple and effective for capillary and venous bleeding. It was the preferred method of fluid management in simple situations, especially when combined with local barrier. In previous attempts with suction it was found that the larger suction tips performed better at collecting fluid. (With very small suction catheters, the fluid tended to migrate up the outside of the catheter.) To test this finding, a large suction cone was attached to the hand-held suction to see if it was easier to use than the standard tip (see photo 4.) It was found that the larger cone negated the suction force and did a poorer job than the standard tip. Indeed, some of the fluid would simply stick to the cone interior due to surface tension (see photo 5.) Using the cone to capture escaped fluid boluses was less effective than allowing the laminar flow/suction to work.

Laminar Flow/Suction

The laminar flow/suction device functioned well for dislodged fluid droplets. In the bleeding model used, surface tension kept most of the capillary and venous bleeding pooled on the surface of the arm. However, if during movement or blotting any fluid boluses were dislodged, they were easily caught in the laminar flow and collected in the suction trap. This was especially useful during times when there was only one surgeon who could not pause to use handheld suction to keep the operating field clear.

More vigorous (arterial type) bleeding was too forceful to be captured in the laminar flow and would pass directly through it. (See photo 6.) However it was noted that without the laminar flow, such bleeding would escape in random and unpredictable fashion. But with the laminar flow present, even though the fluid was not contained, the force of the air flow was sufficient to direct the fluid flow in a predictable direction that subsequently could be captured by an external barrier.

Barrier Sheet

As part of the study, a hyper-absorbant commercially available cloth ("Camel cloth") was evaluated for use as an external barrier. (See photo 6.) This material has pronounced wicking and absorbant properties, especially after being moistened. With the laminar flow device functioning, the direction of fluid escape could be predicted fairly easily and the external barrier positioned to absorb any excess fluids. Something like this was felt to be useful in temporary situations where the degree of fluid escape was greater than anticipated. For excessive fluid loss, a more permanent solution would be preferable.

Integrated System

During an actual suturing scenario with simulated bleeding, the two experimenters worked as a team to accomplish the procedure. It was found that with most of the capillary and venous-type bleeding, local barrier and hand-held suction functioned extremely well to control the bleeding and keep the operative site clear. (See photo's 7 and 8.) When fluid loss became more pronounced, the laminar flow device worked nicely as a back-up to the local methods. (See photo 9.) This integrated system proved to be a simple and effective means of supporting the type of simple procedures anticipated for SSF. Only when forceful fluid loss was present did this system fail in complete containment and another level of support was obviously required.

Cautery Fumes

Using a hand-held disposable cautery device, an orange was cauterized to produce fumes similar to actual surgery. (See photo 10.) These fumes were readily visible and were easily removed with the laminar flow/suction device. With such a device, these types of fumes should not represent a hazard or view obstruction during surgery.

SUMMARY AND RECOMMENDATIONS:

The results of this study and previous investigations show that performing surgical procedures in zero-gravity is feasible provided certain types of restraint and support. The issue of sterile field and hemostasis remain a concern, although this evaluation demonstrated the utility of a modular control system containing local barrier, local suction and laminar flow/suction. It is felt that a laminar flow device might provide an added benefit

of reducing environmental contamination of the operative site.

Due to the obvious limitations of simulated surgical models, it is recommended that these investigations proceed to include live animal subjects in a completely integrated study. This study should be performed using a multi-tiered surgical support system that incorporates local containment, laminar flow and an overhead canopy. The model should investigate hemostasis for all bleeding sources (capillary through arterial) and should be performed in close approximation of actual sterile surgery planned for SSF.

NASA PHOTO REFERENCE

S90-36401 - 02

Preparation of mannequin arm for surgical technique

S90-36404

Surgical trays in microgravity

S90-36412 - 13

Suturing in microgravity

S90-36418 - 19

Suturing in microgravity

S90-36429

Suturing in microgravity

S90-36436

Preparation of sterile surgical field

S90-36438

Suturing in microgravity

S90-36440 - 41

Preparation of the surgical area

S90-36443

Deployment of the surgical tray

S90-36445

Preparation for suturing

S90-36520 - 22

Making an incision

S90-36525 - 27

Preparing the arm for surgery